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## The Box Method

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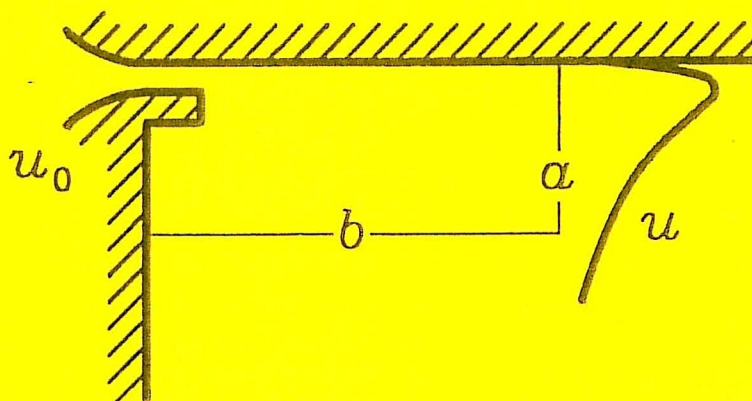
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# **The Box Method - a Practical Procedure for Introduction of an Air Terminal Device in CFD Calculation**

by

Peter V. Nielsen  
Aalborg University

## **Abstract**

The velocity level in a room ventilated by jet ventilation is strongly influenced by the supply conditions. The momentum flow in the supply jets controls the air movement in the room and, therefore, it is very important that the inlet conditions and the numerical method can generate a satisfactory description of this momentum flow. The Box Method is a practical method for the description of an Air Terminal Device which will save grid points and ensure the right level of the momentum flow.

## **Introduction**

Figure 1 shows the decay of the maximum velocity in the flow that runs along the ceiling in a room with two-dimensional recirculating air movement. The velocity level obtained by two different inlet conditions, corresponding to two different supply openings, is retained in the flow along the ceiling. The difference in the velocity level will be retained in the occupied zone as well. A satisfactory description of the inlet conditions is, therefore, very important for the prediction of the flow in the whole room.

Figure 1 also shows that the velocity decay below the ceiling corresponds to the conditions in a wall jet, except close to the end wall opposite the supply opening. This means that the air movement below the ceiling can be expressed by parabolic equations, although the flow as a whole is recirculating and, therefore, described by elliptic equations. This strong upstream influence in the first part of the flow is the background for the wall jet description of boundary conditions for supply openings discussed in this paper.

The momentum flow in the wall jet below the ceiling controls the air movement in a room. For example, the maximum velocity in the occupied zone is proportional to the inlet velocity multiplied by the square root of the supply area, which expresses the square root of the supply momentum flow. Therefore, it is very important that the inlet conditions and the numerical method produce a satisfactory description of the momentum flow.

The supply momentum flow from diffusers depends on small details in the design. This means that a numerical prediction method should be able to handle small details in the order of a few millimetres to room dimensions of many metres. This wide range of geometry necessitates the use of many grid points and demands, therefore, a large computer or a procedure which can reduce the number of grid points.

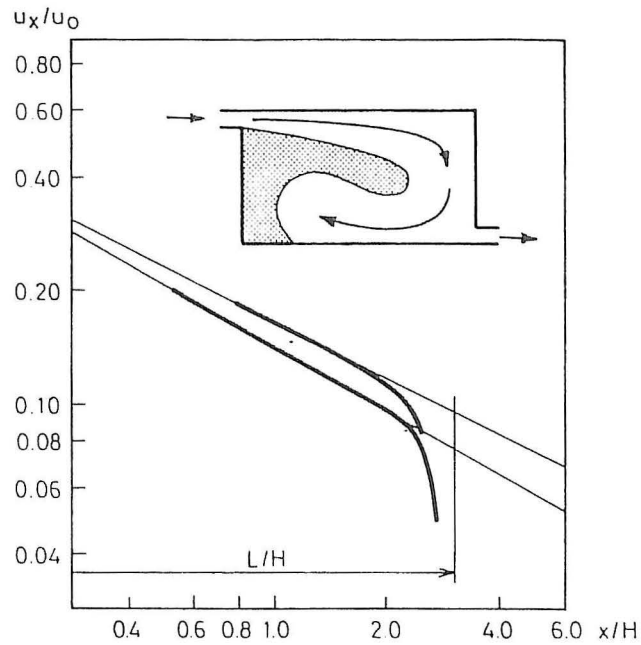


Figure 1. Velocity decay in the flow along the ceiling in a room. Predictions are shown for two different diffusers with the same slot height,  $h/H = 0.0015$  and  $L/H = 3$ , where  $h$ ,  $H$  and  $L$  are slot height, room height and room length, respectively.

### The Box Method

Nielsen (1973) and (1978) was the first to use the Box Method in the numerical prediction of room air movement. This paper describes the method in the case of two-dimensional flow and will mainly be based on relevant chapters in the Ph.D. thesis "Flow in Air Conditioned Rooms" by Nielsen (1974). Other examples are given in (Nielsen 1975, 1989a, 1989b and 1992).

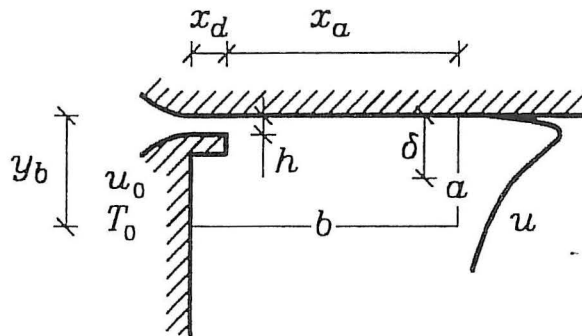


Figure 2. Location of boundary conditions by the Box Method.

Figure 2 shows the location of the boundary conditions around the diffuser used in the Box Method. The details of the flow in the immediate vicinity of the supply opening are ignored, and the supplied jet is described by values along the surfaces  $a$  and  $b$ , see figure 2. Two advantages are obtained by using these boundary conditions. First, it is not required to use a grid as fine as is the case with fully numerical prediction of the development from an inlet flow to a wall jet. Secondly, it is possible to make two-dimensional predictions for supply openings which are three-dimensional, provided that the jets develop into a two-dimensional wall jet or free jet at a certain distance from the openings.

The profiles for the variables  $\phi$  at the surface  $a$  are the universal or the self-preserving profiles for the actual diffuser at the distance  $x_a$ , where  $\phi$  corresponds to velocity  $u$ , temperature  $T$ , concentration  $c$ , turbulent kinetic energy  $k$  and turbulent dissipation  $\varepsilon$ , respectively.

The surface  $b$  in figure 2 shows the other boundary in the Box Method. A parallel flow is assumed at this surface ( $\partial\phi / \partial y = 0$ ).

The length  $x_a$  should be sufficient to locate the surface  $a$  in an area with a fully developed wall jet. The selection of a large  $x_a$  reduces both the gradients of the  $\phi$  values at the surface  $a$  and the solution domain, which means a reduction in grid points and computation time. The length  $x_a$  should, on the other hand, only be a small fraction of the room length  $L$  because the velocity decay may be slightly influenced by the recirculating flow, and it has to be predicted by the elliptic equation.

The height  $y_b$  of the surface  $a$  should be adequate for the momentum flow to be established in the wall jet. Figure 3 shows  $u_x / u_0$  versus  $y_b / \delta$ , where  $u_0$  is the supply velocity,  $u_x$  is the maximum velocity in the wall jet and  $\delta$  is the half width of the wall jet (thickness of the jet to the velocity  $u_x / 2$ ). The figure indicates that  $y_b / \delta = 0.75$  and  $y_b / \delta = 1.0$  shows good results, while  $y_b / \delta = 0.5$  is too small in the given situation. It is necessary to compare the velocity decay in the predictions with measured values, and it is necessary to check the continuity in all profiles in the point  $(x_a, y_b)$ . It is not possible to use a large value of  $y_b / \delta$  because the real profiles in the room are different from the universal wall jet profiles for  $y_b / \delta > 1 - 1.5$ .

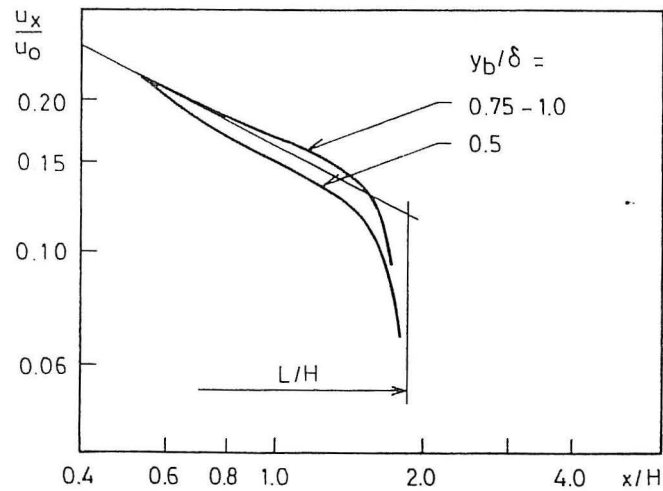


Figure 3. Velocity decay in a predicted wall jet for different values of  $y_b / \delta$ . The velocity decay for  $y_b / \delta = 1.0$  corresponds to measurements in the given situation.  $h/H = 0.003$ ,  $L/H = 1.9$  and  $Re = 1400$ .



The maximum velocity in the profile  $u_x$  at distance  $x_a$  is obtained from the  $K_p$  value of the diffuser, and  $\delta$  is obtained from the  $D_p$  value of the diffuser.  $K_p$  and  $D_p$  values can be obtained from *commercial diffuser catalogues or design guide books* as ASHRAE Fundamentals (1997). The velocity profile can also be obtained from *measurements on the diffuser* used in the prediction. The use of the coefficients related to the actual diffuser is an important aspect of the Box Method because this procedure will ensure the correct profiles at surface  $a$  including the description of the momentum flow.

$u_x$  and  $\delta$  are connected to  $K_p$  and  $D_p$  in the following equations (Schwarz and Cosart, 1961).

$$\frac{u_x}{u_o} = K_p \left( \frac{h}{x_o + x_a} \right)^c \quad (1)$$

$$\frac{\delta}{h} = D_p \frac{x_o + x_a}{h} \quad (2)$$

The velocity profile at the surface  $a$  is given as a universal profile  $u / u_x$ , see e.g. Rajaratnam (1976) and Verhoff (1963).

The temperature level and the concentration level at surface  $a$  are influenced by the values crossing surface  $b$  due to entrainment. It is, therefore, necessary to calculate an energy balance and a mass fraction balance for the volume  $x_a$  times  $y_b$  in front of the diffuser in each iteration. The profiles are similar to the velocity profile except close to the wall where the values are constant corresponding to the minimum or the maximum value in the profile.

The maximum or the minimum temperature in the profile  $T_x$  is obtained from the  $K_{pT}$  value of the diffuser or from measurements on the diffuser.  $\delta_T$  is obtained from the  $D_{pT}$  value of the diffuser or from measurements.

$T_x$  and  $\delta_T$  can be obtained from the following equations.

$$\frac{T_x - T_b}{T_o - T_b} = K_{pT} \left( \frac{h}{x_o + x_a} \right)^c \quad (3)$$

$$\frac{\delta_T}{h} = D_{pT} \frac{x_o + x_a}{h} \quad (4)$$

$T_b$  is the surrounding temperature, i.e. the mean temperature along surface  $b$  in figure 2.

The distribution of turbulent kinetic energy  $k$  at surface  $a$  is given from measurements of  $\overline{u'^2} / u_x^2$ ,  $\overline{v'^2} / u_x^2$  and  $\overline{w'^2} / u_x^2$ , where  $\overline{u'^2}$ ,  $\overline{v'^2}$  and  $\overline{w'^2}$  are the turbulent normal stresses, see e.g. Nelson (1969).

The turbulent dissipation  $\varepsilon$  and the turbulent viscosity  $\mu_t$  are found from the  $u$ ,  $k$  and  $\overline{u'v'}$  profiles, see Verhoff (1963) and Nelson (1969). The turbulent viscosity is given from the Boussinesq hypothesis

$$-\rho \overline{u'v'} = \mu_t \frac{\partial u}{\partial y} \quad (5)$$

where  $\rho$  is the density and  $\overline{u'v'}$  is the turbulent shear stress. The equation assumes that there is a vanishing shear stress at the velocity maximum. This is not the case in asymmetrical jets such as wall jets where  $\mu_t$  will follow the dotted line in figure 4 when it is calculated from equation (5).

The turbulent length scale  $\ell$  is determined from the  $\mu_t$  distribution and the  $k$  distribution according to the following equation

$$\ell = \mu_t / C_\mu k^{0.5} \rho \quad (6)$$

where  $C_\mu$  is a constant or a variable in the case of low turbulent flow. The dotted curve in figure 5 shows the distribution of the length scale  $\ell$ .

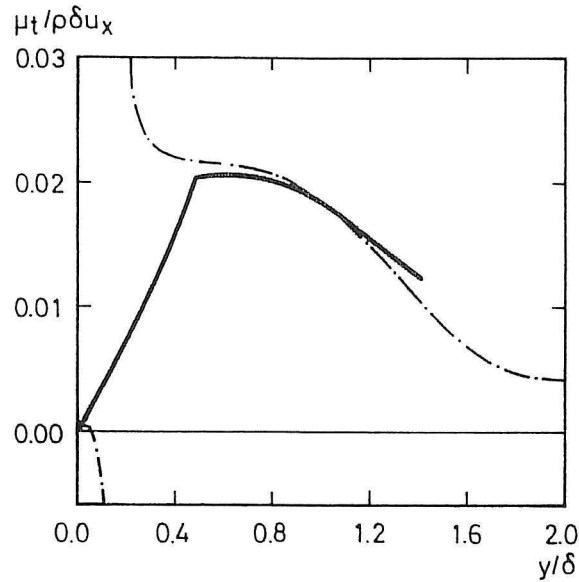


Figure 4. Distribution of turbulent viscosity in a two-dimensional wall jet.

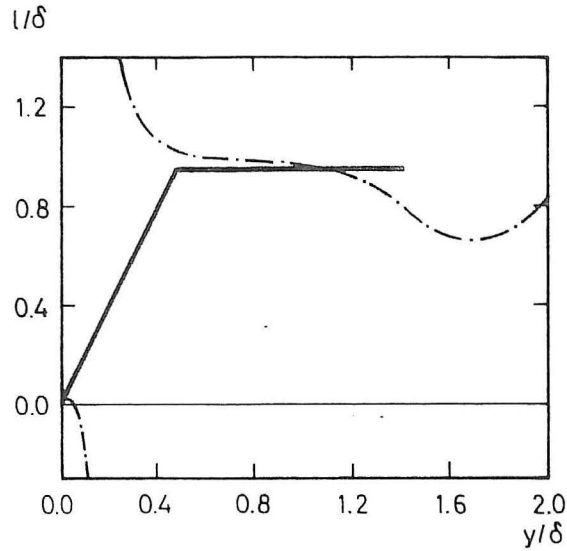


Figure 5. Distribution of the turbulent length scale in a two-dimensional wall jet.

The obtained value for  $\mu_t$  and  $\ell$  cannot be used as boundary values since they assume conditions which are disregarded in the turbulence model. New values are based on the length scale shown as an uninterrupted line in figure 5. This length scale is proportional to the distance from the wall up to  $y/\delta = 0.5$ , and it has a value close to the level found according to equation (5) for  $y/\delta > 0.5$ . If this length scale is used in equation (6) it is possible to obtain the  $\mu_t$  distribution shown as an uninterrupted line in figure 4.

The new length scale  $\ell$  is used to determine the distribution of dissipation along the surface  $a$  according to the equation

$$\varepsilon = k^{3/2} / \ell \quad (7)$$

It is also possible to use the Box Method in the case of special diffuser arrangements. Figure 6 shows the supply opening of a plane jet at a distance  $y_s$  from a parallel surface. Measurements made by Schwartzbach (1973) show that the jet is deflected due to the Coandă effect and develops into a wall jet at a distance  $x_a$  from the supply opening. The curves in figure 6 show the values for  $x_a/h$ ,  $x_o/h$ ,  $u_x/u_o$  and  $\delta/h$ . Based on these data the boundary conditions for a wall jet are determined as before, though it must be pointed out that the turbulence is slightly higher in this case owing to the deflection of the jet.

Appendix A shows further examples of  $K_p$ ,  $D_p$  and  $x_a/h$  values for different types of slot diffusers which can be used in the Box Method. The figures in Appendix A show the variety of supply openings, which can be simulated simply by changing the three values  $K_p$ ,  $D_p$  and  $x_a$ .

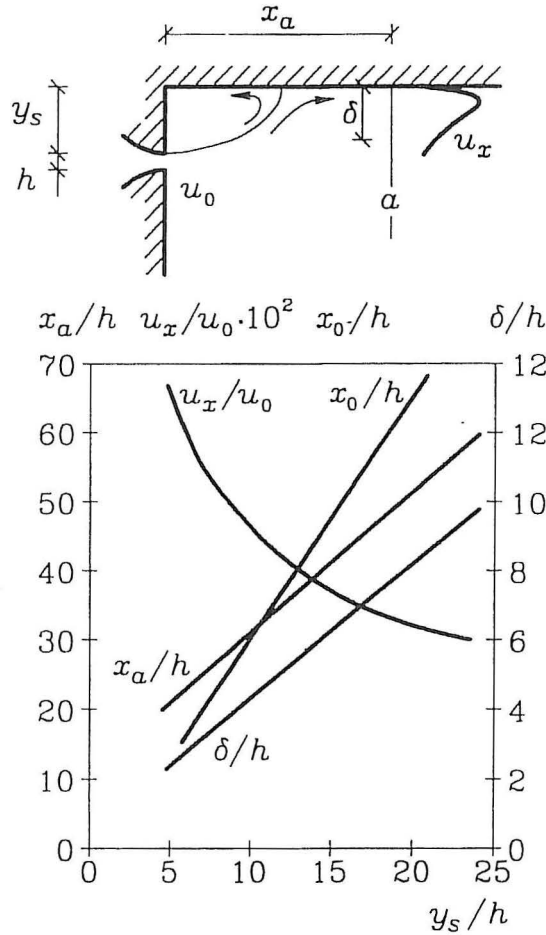


Figure 6. Two-dimensional jet supplied parallel to a surface. After Schwartzbach (1973).

Figure 7 illustrates the use of the Box Method in a special situation where three-dimensional boundary conditions close to the diffusers develop into a two-dimensional flow further downstream in the jet. The figure shows an example of measured and predicted isothermal velocity profiles in a room where the supply consists of 9 nozzles placed at the distance  $H/4$  from the ceiling. The length of the room is three times its height and  $h/H$  is 0.011 where  $h$  is determined as the height in a slot giving the same supply area as the nozzles. The velocity profiles show that the supplied jets merge into a plane free jet which runs close to the ceiling in its further development forming a wall jet. The flow around the supply opening is strongly three-dimensional. However, the measurements show that the recirculating flow formed in the greater part of the room is two-dimensional. The measurements were made by Blum (1956).

The calculated velocity profiles in figure 7 are determined as a numerical solution of the two-dimensional flow equations. In the predictions the supply opening is characterized by the plane wall jet profile which it forms at the distance  $x/H = 1.2$ . It is seen that the agreement between the measured and the calculated velocities is good. The deviation of the maximum velocity in the occupied zone is below 1 % of the supply velocity. The agreement between the measured and the calculated velocity decay in the wall jet below the ceiling is also good. It is seen, however, that the calculated increase in the jet width barely reaches the measured value.

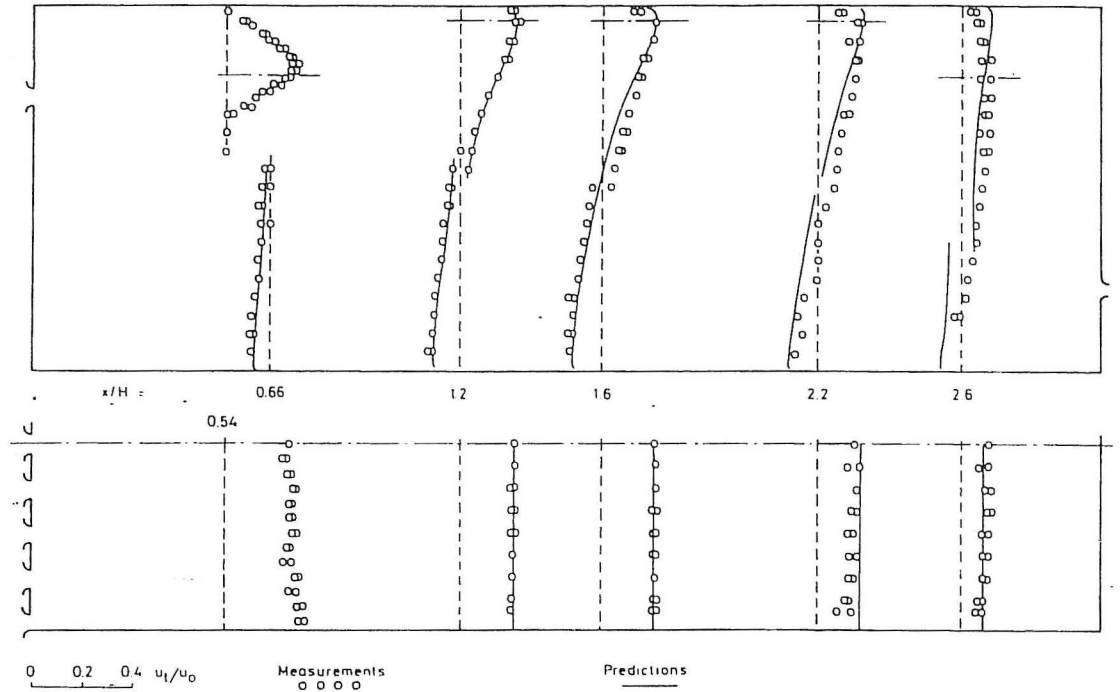


Figure 7. Measurements and predictions of velocity profiles in a room with nine supply nozzles placed at a certain distance from the ceiling. The upper figure shows a vertical section in the middle plane, and the lower figure shows a horizontal section at the heights shown in the upper figure. The calculated velocity  $u_t$  is the total velocity  $(u^2 + v^2)^{0.5}$ .  $L/H = 3.0$ ,  $W/H = 1.0$ ,  $h/H = 0.011$  and the Reynolds number  $Re = 25000$ .  $L$ ,  $H$  and  $W$  are the length, the height and the width of the room, respectively.

The use of a wall jet profile as the boundary value in the calculation in figure 7 is a good example of the simplification that can be achieved. If the actual supply openings had been used as boundary conditions, the calculations should have been performed by an equation system for three-dimensional flow with a strongly increased number of grid points close to the diffusers instead of the equation system for two-dimensional flow. However, this means a severe increase in both the computer storage and the computation time.

### List of symbols

$a$	Control surface at supply opening
$b$	Control surface at supply opening
$c$	Concentration
$C_\mu$	Constant in turbulence model
$D_p$	Growth rate for plane wall jet
$D_{pT}$	Growth rate for temperature profile
$e$	Exponent
$h$	Effective height of diffuser

$H$	Height of room
$k$	Turbulent kinetic energy
$K_p$	Velocity decay coefficient for a plane jet
$K_{pT}$	Temperature decay coefficient for a plane jet
$\ell$	Turbulent length scale
$L$	Length of room
$T_o$	Supply temperature
$T_x$	Minimum or maximum temperature of wall jet
$T_b$	Mean temperature along surface $b$
$u_x$	Maximum velocity in wall jet
$u_o$	Supply velocity
$u'$	Instantaneous deviation from time averaged velocity
$v'$	Instantaneous deviation from time averaged velocity
$w'$	Instantaneous deviation from time averaged velocity
$x_o$	Distance to virtual origin of jet
$x_a$	Distance from diffuser to surface $a$
$x_d$	Distance from wall to diffuser
$y_s$	Distance from ceiling to supply opening
$\delta$	Thickness of wall jet
$\delta_T$	Thickness of temperature profile in jet
$\varepsilon$	Dissipation
$\mu_t$	Turbulent viscosity
$\rho$	Density
$\phi$	Variable ( $u, T, c, k, \varepsilon$ )

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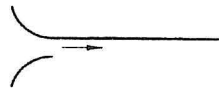

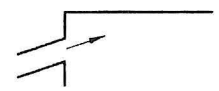
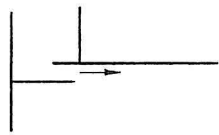

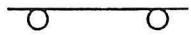
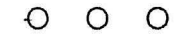
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## Appendix A

### Slot diffusers

Reference	$K_p$	$D_p$	$x_n/h$	$e$	Geometry
Schwarz and Cosart (1961)	5.4	0.068	11.2	0.555	
Myers et al. (1963)	7.05	0.07	14.0	0.63	
Hanel and Scholtz (1978)	3.55	0.087	20.0	$\equiv 0.5$	$Tu < 1 \%$
	3.46	0.104	31.1	$\equiv 0.5$	$Tu > 40 \%$
Förthmann (1934)	4.1	0.082	6.6	0.5	
Hestad (1974)	3.1	0.10	34.0	$\equiv 0.5$	
Hestad (1974)	3.6		$\equiv 0$	$\equiv 0.5$	
Blum (1956)	3.32	0.111	-2.65	$\equiv 0.5$	
	3.16	0.128	-30.25	$\equiv 0.5$	
	2.97	0.135	56.59	$\equiv 0.5$	
Nielsen and Möller (1988)	2.35	0.16		0.5	$Re = 2660$
	2.35	0.10	18.3	0.5	$Re = 4140$
	2.35	0.08	17.7	0.5	$Re = 5610$
	2.35	0.16		0.5	$Re = 1330$
	2.49	0.14	16.3	0.5	$Re = 2070$
	2.69	0.06	49.5	0.5	$Re = 2750$

## Appendix B

### The Box Method

Fortran listing of elements of the Box Method (Nielsen et al. 1978).

```

COMMON
1/COM3/IW,JW,IWM1,IWP1,JWM1,JWP1,XZERO,XD,CUIN,EUIN,CDEL,CTEMP,
2    ETA(33),FETA(33),FIETA(33),ZKETA(33),
3    UMP,UPWJ(25),STU(25)
C
CHAPTER 1 1 1 1 CALCULATION OF WALL JET VALUES 1 1 1 1 1
C
C-----WALL JET PROFILE
C    DATA FROM REPT 626, MAY 63, PRINCETON UNIVERSITY
C    CO-ORDINATES
C    DATA ETA/    .01,.02,.03,.04,.05,.06,.07,.08,.09,.1,.12,.14,.16
1    .18,.2,.3,.4,.5,.6,.7,.8,.9,1,.11,1.2,1.3,1.4,1.5,1.6,1.7,1.8
2    .19,2./
C    VELOCITY PROFILE
C    DATA FETA/    .76,.833,.876,.906,.927,.944,.958,.968,.977,.983
1    .993,.998,1.,.999,.997,.964,.911,.847,.778,.706,.635,.566,.5
2    .438,.380,.327,.279,.236,.198,.165,.136,.111,.09/
C    STREAM FUNCTION DISTRIBUTION
C    DATA FIETA/    .007,.015,.023,.032,.041,.051,.06,.07,.08,.089
1    .109,.129,.149,.169,.189,.287,.381,.469,.55,.625,.692,.752
2    .805,.852,.893,.928,.958,.984,1.006,1.024,1.039,1.051,1.061/
C    TURBULENT KINETIC ENERGY
C    DATA ZKETA/.0346,.0350,.0356,.0360,.0366,.0371,.0379,.0382,.0386
1    .0388,.0395,.0402,.0409,.0416,.0424,.0478,.0529,.0562,.0578
2    .0573,.0548,.0503,.0452,.0398,.0333,.0271,.0211,.0154,.0116
3    .0082,.0057,.0040,.0029/
C-----COEFFICIENTS FOR WALL JET
CUIN=5.395
EUIN=.0555
CDEL=.0678
XZERO=11.2*RSMALL
XD=0.0
C-----MAX VELOCITY IN JET. UM FOR XU(IW) AND UMP FOR X(IW)
UM=UIN*CUIN*(XU(IW)/RSMALL+XZERO/RSMALL-XD/RSMALL)*EUIN
UMP=UIN*CUIN*((X(IW)+XZERO-XD)/RSMALL)*EUIN
C-----BOUNDARY LAYER, DELTA (VEL.=UM/2)
C    DELU= DELTA FOR U-VELOCITY, DELP= DELTA FOR OTHER VARIABLES
C    DELU=CDEL*(XU(IW)-XD+XZERO)
C    DELP=CDEL*(X(IW)-XD+XZERO)
C-----GENERATING STREAM FUNCTION DISTRIBUTION
DO 10 J=2,JW
JP1=J+1
ET=YV(JP1)/DELU
DO 20 L=1,33
IF(ET.LE.ETA(L)) GO TO 30
20 CONTINUE
30 DIFE=(ET-ETA(L-1))/(ETA(L)-ETA(L-1))
STU(JP1)=FIETA(L-1)+(FIETA(L)-FIETA(L-1))*DIFE
STU(JP1)=STU(JP1)*DELU*UM

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C-----GENERATING OF PROFILES FOR OTHER VARIABLES
ETP=Y(J)/DELP
DO 40 L=1,33
IF(ETP.LE.ETA(L)) GO TO 50
40 CONTINUE
50 DIFE=(ETP-ETA(L-1))/(ETA(L)-ETA(L-1))
TE(IW,J)=ZKETA(L-1)+(ZKETA(L)-ZKETA(L-1))*DIFE
TE(IW,J)=TE(IW,J)*UMP*UMP
UPWJ(J)=FETA(L-1)+(FETA(L)-FETA(L-1))*DIFE
XL=2.*Y(J)
IF(XL.GT.0.95*DELP) XL=0.95*DELP
VIS(IW,J)=CMU*DENSIT*XL*(TE(IW,J)**0.5)
ED(IW,J)=(TE(IW,J)**1.5)/XL
10 CONTINUE
C-----GENERATING VELOCITY PROFILE
C ACCORDING TO VOLUME FLOW IN WALL JET
STU(2)=0.0
DO 55 J=2,JW
55 U(IW,J)=(STU(J+1)-STU(J))/SNS(J)
C
CHAPTER 2 2 2 2 2 CALCULATION OF ENTRAINMENT VELOCITY 2 2 2
C
C-----TOTAL VOLUME FLOW IN WALL JET
FLOWW=STU(JW)
C-----MEAN ENTRAINMENT VELOCITY
DO 100 I=2,IWM1
100 V(I,JW)=(FLOWW-FLOWIN/DENSIT)/XU(IW)
RETURN
END

```

Energy balance for the volume  $x_a$  times  $y_b$ , see page 4.

```

C-----WALL JET AREA
C      DT/DY=0 ALONG ENTRAINMENT BORDER
      DO 520 I=2,IWM1
      DO 520 J=2,JWM1
520    T(I,J)=T(I,JW)
C      SURROUNDING MEAN TEMPERATURE TO WALL JET
      TEM=0.0
      DO 530 I=2,IWM1
      TEP=T(I,JW)*SEW(I)
530    TEM=TEM+TEP
      TEM=TEM-T(IWM1,JW)*SEW(IWM1)/2.0
      TEMP=TEM/X(IWM1)
C-----HEAT FLOW INTO WALL JET (TIN=0.0 REF. TEMP.)
      HWJIN=0.0
      DO 532 I=2,IWM1
      HWJ=DENSIT*CPP*V(I,JWP1)*T(I,JWP1)*SEW(I)
532    HWJIN=HWJIN+HWJ
C-----HEAT BALANCE IN WALL JET
      HSLOT=DENSIT*CPP*UIN*TIN*RSMLL
      HWJOUT=HSLOT-HWJIN
      HOUT1=0.0
      HOUT2=0.0
      DO 540 J=2,JW
      ETP=Y(J)/(CDEL*(X(IW)-XD+XZERO))
      HOUT1=HOUT1+DENSIT*CPP*U(IW,J)*TEMP*SNS(J)
      HWJ=DENSIT*CPP*U(IW,J)*UPWJ(J)**PRANDT*SNS(J)
      IF(ETP.LT.0.16) HWJ=DENSIT*CPP*U(IW,J)*SNS(J)
540    HOUT2=HOUT2+HWJ
C      MAXIMUM TEMPERATURE DIFFERENCE IN WALL JET
      DTM=(HWJOUT-HOUT1)/HOUT2
      IF(DTM/(TIN-TEMP).LT.0.0) DTM=0.0
      IF(DTM/(TIN-TEMP).GE.1.0) DTM=0.99*(TIN-TEMP)
C      TEMPERATURE PROFILE
      DO 550 J=2,JW
      ETP=Y(J)/(CDEL*(X(IW)-XD+XZERO))
      T(IW,J)=TEMP+DTM*UPWJ(J)**PRANDT
550    IF(ETP.LT.0.16) T(IW,J)=TEMP+DTM
C      CALCULATION OF CTEMP
      CTEMP=DTM/(TIN-TEMP)/(UMP/UIN)
C      MAINTAINING CALCULATED TEMPERATURES IN WALL JET AREA
      DO 560 I=2,IW
      DO 560 J=2,JWM1
      SU(I,J)=GREAT*T(I,J)
560    SP(I,J)=-GREAT

```

$$\text{ETA} \sim \eta$$

$$\text{FETA} \sim f(\eta) \quad (= u / u_\lambda)$$

$$\text{FIETA} \sim \int_0^\eta f(\eta)$$

$$\text{ZKETA} \sim k / u_\lambda^2$$

$$\text{CUIN} \sim K_p$$

$$\text{EUIN} \sim \epsilon$$

$$\text{CDEL} \sim D_p$$

$$\text{XZERO} \sim x_0$$

$$\text{RSMALL} \sim h$$

$$\text{UIN} \sim u_0$$

$$\text{XD} \sim x_d$$

$$\text{UM} \sim u_\lambda \text{ for } u \text{ velocity}$$

$$\text{UMP} \sim u_\lambda \text{ for other variables}$$

$$\text{DELU} \sim \delta \text{ for } u \text{ velocity}$$

$$\text{DELP} \sim \delta \text{ for other variables}$$

$$\text{EP} \sim \eta \quad (= y / \delta) \text{ for } u \text{ velocity}$$

$$\text{ETP} \sim \eta \quad (= y / \delta) \text{ for other variables}$$

$$\text{STU(JP1)} \sim \text{Stream function}$$

$$\text{TE(IW,J)} \sim k$$

$$\text{VIS(IW,J)} \sim \mu_t$$

$$\text{XL} \sim \ell$$

$$\text{UPWJ(J)} \sim u / u_\lambda$$

$$\text{ED(IW,J)} \sim \epsilon$$

$$\text{U(IW,J)} \sim u \text{ velocity at surface } a$$

$$\text{V(I,JW)} \sim \text{entrainment flow at surface } b$$

$$\text{T(I,J)} \sim \text{temperature}$$

$$\text{DTM} \sim \Delta T_t$$

$$\text{PRANDT} \sim \sigma_h$$

$$\text{T(I,JW)} \sim \text{temperature at surface } b$$







